Establishment of an Ozone Bioindicator Study Site at Mountain View School

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Background

What is an ozone bioindicator garden?

A bioindicator is a plant that exhibits a typical and verifiable response when exposed to a specific environmental stressor such as ozone. A bioindicator garden includes species of plants that are both ozone-tolerant and ozone-sensitive in order to monitor damage caused by ozone exposure. The purpose of a bioindicator garden is to raise environmental awareness about air pollution by observing and recording ozone-induced foliar injury on these plants in a controlled, on-going experiment.[1]

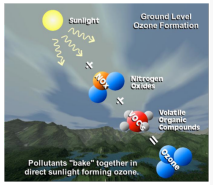
Why study ozone?

Exposure to ground-level ozone effects the health of humans and the environment, causing respiratory difficulties in people who have lung disease such as asthma. Young children and the elderly are especially sensitive to adverse effects from ozone exposure, making it difficult for them to breathe.[2] Symptoms of ozone exposure to vegetation includes stippling on leaves and decreased crop growth. Significant adverse responses in both humans and plants occur at or close to the ambient (background) concentration of ozone.

How does ozone form?

Ozone in the stratosphere forms naturally and is helpful to living things because it protects us from harmful ultraviolet radiation. However, ozone in the lower troposphere, where we live and breathe, is formed as a secondary product of a series of complex chemical reactions that occur in the atmosphere between volatile organic compounds (VOC's,) such as hydrocarbons, and nitrogen oxides in the presence of sunlight.[3] The ingredients for these chemical reactions have both natural and man-made origins. For example, VOC's are emitted as a result of combustion (burning of fuels at high temperatures) from motor vehicles, power plants and factories, as well as from trees in the form of isoprenes or monoterpenes.[4]

Ozone Chemistry



Ground Level Ozone Formation
[Image from http://aura.gsfc.nasa.gov/images/features/ground_ozone.jpg]

DURING THE DAY: Ground-level ozone is produced when hydrocarbons react with NO_2 in the presence of sunlight.

During combustion, nitrogen reacts with oxygen to create nitric oxide:
$N_2 + O_2 \rightarrow 2NO$

Nitric oxide from auto engines reacts with oxygen in the air to form nitrogen dioxide:
$2NO + O_2 \rightarrow 2NO_2$

Nitrogen dioxide is irradiated with bright light (sun):
$NO_2 + (light) \rightarrow NO + O$

A single oxygen atom is very reactive and readily attaches to a oxygen molecule creating ozone:
$O + O_2 \rightarrow O_3$

AT NIGHT: The predominant reaction is ozone reacting with nitric oxide to form nitrogen dioxide and oxygen:
$O_3 + NO \rightarrow NO_2 + O_2$

Location of Study

Chester Monitoring Station & Mt. View School

Mt. View School is located in Mendham Borough, less than 10 miles away from the Chester Monitoring Station, which is ideal for students to correlate station data with foliar injury observations collected in the newly established ozone bioindicator garden at the school. The purpose of the Chester station is to measure background air toxin concentrations in northern New Jersey.[5] Both Chester and Mendham are located in Morris County approximately 40 miles west of NYC. The Chester-Mendham area is considered a rural-suburban environment, with 42% of Chester's land alone permanently protected from development.[6]

Morris County highlighted in the State of NJ; Chester Township highlighted in Morris County.

Chester Station School location relative to Mt. View.
(Image courtesy of Google Earth)

Chester Monitoring Station
Lat 40.787628, Long -74.676300
Elevation: 912 ft. (Image: mapquest.com)

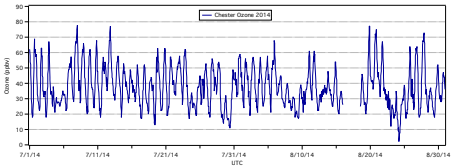
References

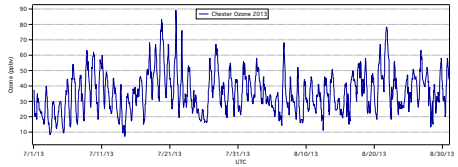
[1,9] Ladd, Irene, John Skelly, Margaret Pippin, and Jack Fishman. "Ozone-Induced Foliar Injury Field Guide." (n.d.): n. pag. *NASA Bioindicator Garden Project*. NASA, 15 Mar. 2011. Web. 9 July 2015.
[2] "Health Effects." United States Environmental Protection Agency. N.p., 26 Nov. 2014. Web. 10 July 2015. <http%3A%2F%2Fwww.epa.gov%2Fgroundlevelozone%2Fhealth.html>.
[3] "Chemistry in the Sunlight : Feature Articles." Chemistry in the Sunlight : Feature Articles. EOS Project Science Office Goddard Space Flight Center, n.d. Web. 10 July 2015. <http://earthobservatory.nasa.gov/Features/ChemistrySunlight/chemistry_sunlight3.php>
[4] Vanshnoy, C. K. "EnviroNews Archives - VOC Emission by Plants: Significance and Implications." EnviroNews Archives - VOC Emission by Plants: Significance and Implications. Environews, 1 Jan. 2007. Web. 13 July 2015. http://isebindia.com/05_08/07-01-2.html.
[5] "Ambient Air Monitoring Network Plan 2014." (n.d.): n. pag. Web. 10 July 2015. http://www.njaqinow.net/NJ-network-plan-2014.pdf
[6] "Chester Township, New Jersey." Wikipedia. Wikimedia Foundation, n.d. Web. 10 July 2015. https://en.wikipedia.org/wiki/Chester_Township,_New_Jersey.
[7] "National Ambient Air Quality Standards (NAAQS)." EPA. Environmental Protection Agency, 21 Oct. 2014. Web. 13 July 2015. http://www.epa.gov/air/criteria.html#3.
[8] "Area Map | Green Book | US EPA." EPA. Environmental Protection Agency, n.d. Web. 10 July 2015. http://www.epa.gov/airquality/greenbook/mapbtr_2008.html.

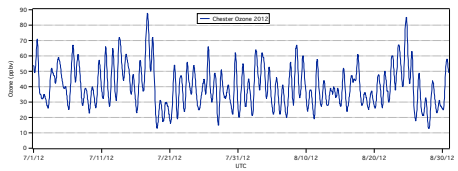
Ozone and NO_2 Fluctuations in Chester

The graphs below compare the seasonal fluctuations of ozone and NO_2 from data retrieved from the Chester monitoring station via AirNow Tech for 2012, 2013, and 2014 to characterize the measured concentration of ozone in recent years leading up to the establishment of Mt. View's Ozone garden. Of specific interest are the ozone levels during the summer months, since these measurements will be compared with foliar injury observations from our ozone garden. Ozone levels are higher in the summer when days are longer and hotter, while NO_2 tends to be higher in the winter when there is less sunlight and increased emissions from the burning of fossil fuels for heating. An interesting night pattern in the data from Chester is that ozone often does not reach zero, especially when ozone is already elevated during the day.

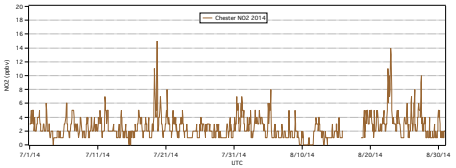
Ozone concentrations in SUMMER MONTHS
July 1-August 31

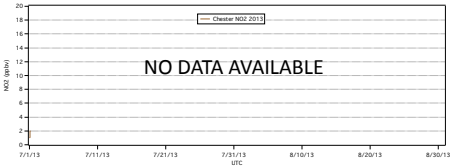


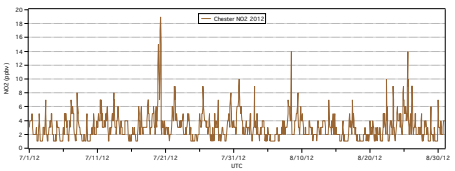




NO_2 concentrations in SUMMER MONTHS
July 1-August 31







National Ambient Air Quality Standards (NAAQS)

As a result of the Clean Air Act, the EPA has set standards for pollutants harmful to public health and the environment, including ozone and NO_2. The 8-hour ozone standard has been set at 75 ppb while the standard for NO_2 is 100 ppb as a 1-hour average.[7] As of January 2015, New Jersey in general is in marginal non-attainment for ozone.[8] Looking at the graphs above during the summer months, ozone occasionally peaks above 75 ppb when averaged hourly in Chester and is far from the 100 ppb 1-hour average for NO_2.

[Image: http://www.epa.gov/airquality/greenbook/mapbtr_2008.html]

Ozone Induced Foliar Injury

Monitoring foliar injury to highly sensitive plants is a useful method to detect ground-level ozone pollution in areas that are not currently being monitored. Foliar injury due to ozone exposure has been well documented in sensitive native species such as cutleaf coneflower and common milkweed. In addition, ozone sensitive and ozone tolerant cultivars have been developed by scientists at the USDA-Agricultural Research Service, North Carolina State University over the past several years for purposes of detecting ozone air pollution. Healthy plants take in ozone from the air along with carbon dioxide through their stomata, small pores on the underside of the leaf that allows gases to enter or leave. Exposure to ozone can interfere with the plant's ability to produce and store food, weaken the plant so that it is more susceptible to disease, and affect the plants ability to reproduce.[9] Symptoms specific to the species will usually begin to appear on plants in late June or early July and increases throughout the summer. (J.M Skelly, NASA, Plant Pathology Consultant, personal communication, 2015)

Snap Beans: The photo on the left shows a healthy ozone-tolerant trifoliate leaf. Damaged ozone-sensitive snap bean showing upper surface stippling and advancing dead areas of the older leaves appears on the right.

Common Milkweed is considered one of the best natural bioindicators of ozone. The major symptom is increasing stippling throughout exposure.

Cutleaf Coneflower: Initial injury can be seen in the photo on the left using a hand lens to reveal slight stipple and clear veins. The photo on the right shows that as the season progresses, advanced injury is indicated by general leaf reddening.

Student Involvement

Using My NASA Data & GLOBE

Participation in NASA LEARN has sparked many new learning endeavors at Mountain View School. As a result of a First Energy STEM grant, we were able to purchase two sun photometers to measure aerosol optical depth, a pyranometer to measure solar irradiance (radiant energy), a U-tube thermometer to measure minimum and maximum daily temperatures. Through collaboration with Industrial Arts Teacher Paul Damato, students are constructing an instrument shelter to house the U-tube thermometer for participation in the Global Learning and Observations to Benefit the Environment (GLOBE) Program. Completion of the shelter is anticipated for the fall of 2015 for students to begin collecting and inputting data into GLOBE's database.

Studying atmospheric conditions using GLOBE's satellite images.

Using MY NASA DATA to perform a comparison study between two atmospheric variables.

Students constructed homemade clinometers to estimate height of nearby buildings and trees for GLOBE instrument shelter placement.

In Industrial Arts students are measuring and cutting pine to build a GLOBE Instrument Shelter for Mt. View School grounds.

Investigating Sky Color and the relationship to the presence of aerosols in the atmosphere through NASA S'COOL "Sky Conditions" activity.

Ozone Bioindicator Garden

In the spring of 2015, students planted an ozone garden in Mountain View School's Outdoor Learning Center to study how some plants can be used as bioindicators for the presence of ground-level ozone in the atmosphere. For a comparison study, ozone tolerant and ozone sensitive varieties of snap beans and potato were planted as well as ozone sensitive varieties of common milkweed and coneflower. Students will monitor growth and health of these plants for specific ozone damage to leaves including stippling along the upper side of the leaves. This authentic study ties in all of Earth's Systems, which is a huge emphasis in 6th grade science- atmosphere, biosphere, geosphere, hydrosphere.

Establishing our ozone garden has been a true community effort! Garden club students prepared the beds, 5th grade students planted ozone sensitive and ozone tolerant potato and snap bean plants during their study of ecosystems, and 6th grade students completed planting of the second bed with ozone sensitive and ozone tolerant milkweed.

Bioindicator species planted

- Ozone sensitive (S-156) and ozone tolerant (R-123) **snap beans** were planted as seeds to establish perennials for a comparison study. These seeds were developed by the USDA-Agriculture Research Service at NC State University for the purposes of detecting ozone air pollution.
- Tubers of ozone sensitive **La Chipper** and ozone tolerant **Superior** potatoes were planted for a comparison study.
- Ozone sensitive **Common Milkweed** seeds and **Coneflower** rosettes were planted to establish perennials.

Acknowledgements

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